FISHERY RESEARCH

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Project 8. Hatchery Trout Evaluations

Subproject 1. Synopsis of Nationwide Strategies for High Mountain Lake Management

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TABLE OF CONTENTS

Subproject 1. <u>Synopsis of Nationwide Strategies for High Mountain Lake Management</u>

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ABSTRACT

Information on nationwide strategies for high mountain lake management was collected and compared with the alpine lake program in the Idaho Department of Fish and Game (IDFG) Clearwater Region, where some of the most intensive alpine lake investigations and management applications implemented by IDFG have occurred. Comparisons with respect to stocking rates, fish size at stocking, time of stocking, and rotation interval indicate management practices are quite similar nationwide. Fish are usually stocked as fry or fingerlings (mostly fingerlings in the IDFG Clearwater Region), and base stocking rates for Arctic grayling *Thymallus arcticus*, cutthroat trout *Oncorhynchus clarki*, and rainbow trout *O. mykiss* generally range from 100 to 250 fish/acre (generally less than 200 fish/acre in the IDFG Clearwater Region). Fish are usually stocked sometime between July and September, depending on ice conditions and fish availability (August to September in the IDFG Clearwater Region). Rotation intervals between 2 to 4 years are common (3 years in the IDFG Clearwater Region).

Recommendations for the IDFG alpine lake program are: 1) continue categorization of lakes into fishery management classifications; 2) refine stocking practices by developing models based on productivity and fish population characteristics and stock at 200 or less fingerlings/acre until these models are developed; 3) stock every 2 to 4 years depending on access, fishing pressure; lake productivity, and angler preference; 4) resurvey lakes at least every 5 years when changes in a fishery are expected; 5) continue reducing exotic-to-drainage introductions, continue research and development of native strains, conduct further research on the effects of lake stocking on indigenous trout, and determine angler preferences; and 6) develop a high mountain lake database and assessment manual by 2000.

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INTRODUCTION

Over the past 50 years, the Idaho Department of Fish and Game (IDFG) has stocked about one third of the state's 2,000 or so alpine lakes with native and exotic salmonids. Although the Alpine Lakes Fisheries Program comprises a small part of IDFG's overall fisheries agenda, this program rates highly in terms of angler satisfaction with mountain lake fisheries (Horton and Ronayne 1995).

Stocking fish into some of Idaho's alpine lakes is one of the methods IDFG is using to meet the statewide fisheries management goal of increasing and diversifying sport fishing opportunities for the public. However, high mountain lake ecosystems are fragile and, as with any natural resource, must be managed with exceptional care. This synopsis will review nationwide strategies for the management of high mountain lakes. Innovative approaches that may improve high mountain lake fisheries in Idaho will be considered for incorporation into the IDFG Comprehensive Alpine Lakes Management Plan.

OBJECTIVES

1. Prepare a synopsis of nationwide strategies for high mountain lake management.

2. Compare nationwide strategies for high mountain lake management with the IDFG program.

3. Provide recommendations for high mountain lake management in Idaho.

METHODS

I contacted state biologists nationwide for information on their high mountain lake fisheries programs. Of specific interest was information on stocking criteria, rates, timing, frequency, and models; size of fish, species, and strains stocked; and monitoring procedures. These practices were compared with those used in the current IDFG program.

RESULTS

<u>Western United States</u>

Arizona

Mountain lake management in Arizona falls into two categories - Intensive Use and Basic Yield (Arizona Game and Fish Department 1990). However, none of the mountain lakes in Arizona are truly alpine, nor are they as isolated as Idaho lakes (Joseph Janisch, Arizona Game and Fish Department, personal communication). These lakes are generally located in close proximity to tourist centers, developed or improved campgrounds, and day-use or other high-use areas other than major metropolitan centers.

The management intent under the Intensive Use category is to provide a put-and-take fishery. Catchable-sized fish are stocked into lakes where the demand for harvest cannot be supported by other management techniques. Effort ranges from 10 to 100 angler-days per acre per week, and angler harvest of greater than 50% by number is desired. Little or no natural reproduction occurs in lakes under this category and/or productivity is such that growth rates and fish numbers cannot meet demands. Catchable (8 to 10 in) rainbow trout *Oncorhynchus mykiss* or brown trout *Salmo trutta* are stocked at a rate of 30 to 400 fish/acre (8 to 114 Ib/acre) per stocking (frequency unknown); incentive-sized trout (> 11 in) are stocked at 2 to 10 fish/acre (1 to 5 Ib/acre) in the same waters as smaller fish.

Lakes in the Basic Yield category are characterized by natural productivity sufficient to produce an acceptable spot fishery from natural production and/or fingerling, subcatchable, or catchable fish plants. These lakes are not subject to special regulations. Effort in these lakes is considerably lower than those in the Intensive Use category, ranging from 3 to 15 angler-days per acre per week. A harvest goal of greater than 110% of weight stocked is desired, with fish ranging in size from 8 to 15 in. Rainbow or brown trout fingerlings (< 4 in) are stocked at 600 to 800 fish/acre (6 to 10 Ib/acre) per stocking (frequency unknown), subcatchables (5 to 7 in) at 42 to 700 fish/acre (3 to 466 Ib/acre), and catchables at 30 to 400 fish/acre.

California

Stocking guidelines under the General Trout Policy (California Fish and Game Commission 1995) mandate that: 1) stocking will be utilized only when necessary to augment natural reproduction; 2) stocking fingerling and subcatchable trout will take priority over stocking catchable-sized trout when smaller fish will maintain a satisfactory fishery; and 3) hatchery fish will not be stocked in waters where they may compete or hybridize with trout that are threatened, endangered, or a species of special concern. Because the golden trout *O. aguabonita* is designated as the state fish of California, the Golden Trout Policy prevails over the General Trout Policy if the two are in conflict. Outstanding features of the Golden Trout Policy include provisions that: 1) permit reservation of barren lakes by the California Department of Fish and Game (CDFG) for future stocking of golden trout; 2) maintain broodstock in lakes set aside for the sole purpose of egg production; 3) extend the range of golden trout through wild fish or fingerling plants in native waters, or in other waters possessing adequate spawning grounds; and 4) preclude stocking of rainbow trout and other trout species in designated golden trout waters (generally located in high mountain areas).

Stocking densities in wilderness and back country lakes are recommended to be no greater than 225 age 0 rainbow trout/surface acre by Chase (1992, cited by Brodderick 1995), with adjustments based on lake size, productive potential, and the presence or absence of a self-reproducing trout population. Chase reported lake-to-lake variation in rainbow trout growth appeared to be best explained by the abundance of aquatic plants (particularly *Potamogeton*), lake surface area, and alkalinity. Another factor possibly related to lake productivity is the amount of meadow habitat draining into a lake. He recommended further research on the relationship between alkalinity, conductivity, pH, aquatic plant abundance, meadow drainage area, and stocking density and fish growth.

Colorado

High mountain lakes in Colorado range in elevation from 7,170 to 13,420 feet, in area from 1 to 500 acres, and in depth from 1 to 265 feet. Most lakes do not contain indigenous game fish, but surveys show game fish are present in over 800 of 2,000+ lakes due to stocking. Nelson (1988) provides a comprehensive guide for the management of alpine lakes, which he qualitatively divides into three categories:

> Type 1: 8,000 to 10,000 feet elevation, shallow, considerable littoral area, warm, permanent inlet, relatively accessible, rooted aquatics, benthic amphipods, zooplankton and terrestrial insects common;
>
> Type 2: 10,.000 to 12,000 feet elevation, deeper, less littoral area, colder, small or intermittent inlet, less accessible, few plants, benthic midge/caddis larvae and pupae, zooplankton and terrestrial insects common; and
>
> Type 3: 12,000 to 13,000 feet elevation, shallow to deep, little littoral area, cold, snowmelt inlet, remote access, no plants, benthic midge/caddis larvae and pupae, zooplankton and terrestrial insects common.

Nelson (1988) advises there are no definite boundaries between these general classifications other than elevation, but they are useful for relating environment to the success of the species stocked in them. Rainbow trout, cutthroat trout *0. clarki*, brown trout, and brook trout *Salvelinus fontinalis* all do well in Type 1 lakes. Lake trout *S. namaycush* may also do well, but there is no information available for this species. Snake River cutthroat trout are better suited to productive, low elevation lakes. Rainbow and cutthroat trout also perform well in Type 2 lakes, but brook trout have a propensity to overpopulate. Lake trout grow slow until they switch to a piscivorous diet, but do well in brook trout lakes due to their ability to become large predators. Rainbow trout have done well in some Type 3 lakes, but cutthroat trout seem to be better suited to these high elevation environments. Brown, brook, and lake trout do not do well in Type 3 lakes.

Lakes with single species of trout comprise about 72% of those stocked in Colorado. Competition for food and lack of forage variety limit the potential for multispecies combinations. Competition between rainbow and cutthroat trout is more pronounced than between either species and brown trout. Combinations of rainbow or cutthroat trout and brook trout are usually undesirable. Changing from cutthroat to rainbow trout and vice versa can generally be accomplished by simply changing the species stocked. However, changing from brook trout to another species usually means eradication of the brook trout population. Chemical treatment can be problematic due to restrictions by agencies that manage public land. Complete kills can also be difficult to achieve. However, biological control (e.g., stocking brown or lake trout into brook trout lakes) can eventually result in thinning of the brook trout population and production of a few large fish of the other species.

Nelson (1988) recommends stocking densities based on lake elevation and fishing pressure, but indicates incorporation of environmental data into the basic model, particularly alkalinity, would better suit management requirements. Basic stocking rates, predicated on aerial plants of rainbow trout fingerlings (2 in) and medium fishing pressure (10 to 100 angler trips per acre, where one trip = 3 to 4 h), are calculated by the relationship:

fish/acre = antilog [3.42 - 0.00014 (elevation in feet)].

In order to provide for varying conditions, ±50% variation is allowable. Reasons for stocking less than the basic rate include stocking from the ground or hovering helicopter (because better survival is expected), stocking larger fish, imposition of special regulations, need for better growth rates, and very low alkalinities (< 10 mg/1). Reasons for stocking more than the basic rate include significant increases in fishing pressure and a need to supply a greater number of catchables (9 to 11 in) as opposed to fewer quality size fish (12 to 16 in). In practice, stocking rates for rainbow and cutthroat trout range from 50 to 200 subcatchable (0.8 to 4.1 in) fish/acre; rates for subcatchable (2.1 to 2.9 in) brook trout range from 25 to 500 fish/acre.

Basic stocking rates are based on annual plants and this is recommended; particularly for rainbow trout. Alternate year plants of cutthroat and brown trout are acceptable because of their slow growth and higher survival rates. However, Nelson (1988) recommends stocking frequency be related to size and use of a given lake. Small (< 5 acres), remote, and infrequently-used lakes could be stocked in alternate years, if at all. Larger lakes (> 10 acres) and more accessible smaller lakes could be stocked on an annual basis.

Growth of rainbow trout stocked according to the elevation-medium fishing pressure model was evaluated in 37 lakes. The average length of age 1 fish was 6.4 in (4.5 in annual growth increment), 9.5 in at age 2 (3.1 in increment), 11.8 in at age 3 (2.3 in increment), and 13.3 in at age 4 (1.5 in increment). There was a t 1 in variation in length at age 4 among different plants in the same lake, and a ±2 in variation in length at age 4 between different lakes. Cutthroat and brown trout exhibited slower growth, but better survival than in comparable plants of rainbow trout. These species eventually reached the same or greater size than rainbow trout.

Depending on initial stocking density, at survival rates of less than or equal to 30% essentially all fish are gone after 3 years, at 40% to 50% survival-after 4 to 7 years, and at 60% to 70%-after 7 to 12 years. Domestic strain rainbow trout usually have lower survival rates than wild-type brook, brown; cutthroat, or rainbow trout.

Analysis of fish production costs, with respect to relative costs for different sized fish, shows only a 6% return of fish stocked at 1 in would be necessary for the cost to be the same as for an 80% return of fish stocked at 9 in. The corresponding return of fish stocked at 2 in is 12%, and for 3 in fish, 19%.

Nelson (1988) reports trout populations in high mountain lakes in Colorado are relatively stable, given they are maintained by natural production or stocking. Change can occur, however, through changes in fishing pressure, stocking policy, and regulations, as well as natural or human causes affecting lake environments or fish populations. Therefore, reasons for mountain lake surveys or resurveys should be based on the knowledge or expectation that such changes have occurred or will occur. He recommends a minimum 5-year survey cycle in lakes where changes are expected. A typical lake survey may include collection of the following data:

Physical/Chemical
- Watershed area, surface elevation, surface area, shoreline length, maximum depth, mean depth, volume.
- Surface/bottom temperature, surface/bottom dissolved oxygen, surface conductance, surface total alkalinity, surface total solids, Secchi disk depth.

Zooplankton
- Near bottom-to-surface vertical haul, no. 10 mesh, at least one sample taken between July and September.

Phytoplankton/Primary Productivity
- Phytoplankton: near bottom-to-surface vertical haul, 25 micron mesh.
- Primary Productivity: ^{14}C light and dark bottle method.

Fish Populations
- Variable mesh (½ to 2 in) gill nets, minimum of two nets set overnight for routine qualitative sampling, 3 nets for 11 to 20 acre lakes plus an additional net per each 20 acre increase when larger samples are required for density and age structure estimates, maintain gear type and placement consistency for comparative purposes.
- Species, sex, length, weight, stomach samples, scales (rainbow trout), otoliths (cutthroat, brook, and lake trout).

Nevada

Nevada's high mountain lake resource is minimal and as such, receives minor emphasis (Gene Weller, Nevada Department of Conservation and Natural Resources, Division of Wildlife, personal communication). However, a management plan, which will serve as the basis for discussion of the Nevada program, has been prepared for lakes in the Ruby and east Humboldt mountains (Green 1995). These lakes are managed individually, based largely on past experience.

Seventeen alpine lakes provide fisheries in the Ruby and east Humboldt mountains. These lakes range in elevation from 8,600 to 10,100 feet, in surface area from 2 to 29 acres, and in maximum depth from 6 to 155 feet. Eleven of these lakes have self-sustaining brook trout populations, two of which may also have lake trout, and six have established cutthroat trout populations that require periodic augmentation. An additional eight lakes have been declared unsuitable for fish.

The 11 brook trout lakes are managed as "wild" fisheries. There is no planned augmentation of these populations through stocking, unless total loss occurs through winterkill or overharvest. Lake trout have been introduced into two of these lakes to help correct overpopulation problems. Fishery and habitat condition surveys are scheduled to take place once at each lake between 1995 and 2004.

The six cutthroat lakes are managed as "unique" and/or "quality" fisheries. These populations are augmented by stocking since natural recruitment is generally lacking. Stocking of cutthroat trout fry is scheduled to occur every 3 years at each lake between 1995 and 2004. Fishery and habitat condition surveys will generally take place at the same rate. Stocking densities are based on trend-condition data collected during the fishery and habitat surveys. Although stocking density information is unavailable, in one lake where a fishery is being established, cutthroat trout fry have been stocked at rates ranging from about 200 to 1,200 fish/acre.

Eight lakes have been declared unsuitable for fish. These lakes range in elevation from 8,200 to 9,783 feet, in surface area from 2 to 10 acres, and in maximum depth from 8 to 17 feet. Limiting factors include small size, shallow depth, insufficient inflow during winter periods, and seasonal water loss or dry-up. Concerns regarding contamination of the genetic integrity of wild stocks in outlet streams and poor survival from past stocking efforts have also influenced these determinations.

Fishery and habitat surveys are periodically conducted to gather trend and condition information. The following data may be collected:

Water Quality
- Dissolved oxygen, carbon dioxide, alkalinity, pH, and water temperature data are generally collected at the surface, but sometimes subsurface and/or midrange samples are taken.
- Secchi disk depth.

Invertebrates
- Qualitative Eckman dredge benthic macroinvertebrate sample.
- Qualitative ocular insect sample along shoreline and littoral areas.

Fish Population
- Overnight gill net sets.

New Mexico

Eighteen lakes in the northeast region of New Mexico are stocked (Bob Akroyd, New Mexico Game and Fish, personal communication). These lakes range in elevation from 11,000 to 12,500 feet and are not natural water bodies per se, but are generally associated with makeshift dams. Natural reproduction does not occur in these lakes.

Snake River cutthroat trout are currently being stocked, but New Mexico is trying to develop a hatchery program for native Rio Grande cutthroat trout. Fry are stocked by helicopter in the spring or fall depending on availability. Small lakes (1 to 5 acres) are stocked with 5,000 fish, large lakes (5 to 8 acres) with 15,000. These lakes are generally stocked on an annual basis, but the hiatus is sometimes as long as 2 years. No information is available on growth, harvest, or survival.

Oregon

About 470 lakes are stocked in the Cascade, Wallowa, Elkhorn, and Strawberry mountains in central Oregon. Lakes in the Cascades are stocked with a helicopter, with remaining areas stocked by fixed-wing aircraft. The high lake stocking program is one of the most cost-effective conducted by the Oregon Department of Fish and Wildlife. Benefit cost ratios have been estimated to range from $150 to $350 benefit per dollar expended. On the average, each lake costs approximately $100 to stock (Bob Hooton, Oregon Department of Fish and Wildlife, personal communication).

Brook, rainbow, and cutthroat trout are among the most commonly stocked species, but brook trout comprise the majority of fish stocked. The other species have been tested extensively, but they have never performed as well as brook trout. Target size is 250 fish/lb for release in July. Stocking density is initially set at 100 fish/surface acre and then adjusted depending on ease of access and angling pressure through experimentation. Popular, relatively accessible lakes are more likely to be stocked at higher densities to adjust for fishing mortality. Although lakes are generally stocked every other year, remote lakes with light use may only be stocked once every 4 years.

Lakes with natural recruitment are not routinely stocked. Also, lakes with native trout are largely protected from stocking. However, naturalized populations of brook trout have been established in outlet streams of many lakes and impacts on native cutthroat and rainbow trout are unknown.

Virtually all lakes presently stocked have had physical and biological surveys conducted on them. Most of this work was done in the 1950s and 1960s. When possible, remote lakes are currently surveyed by biologists every 5 to 7 years. More frequently, angler volunteers are recruited to monitor stocking success at wilderness lakes. Historically, biologists set gill nets to evaluate stocking success. Today, much of the work is done through snorkel observations.

Utah

Wilson and Pettengill (1986, 1988) give recommendations for alpine lake management in two drainages of the Uinta Mountains in northern Utah. These reports will provide the basis for a general discussion of management strategies for mountain lakes in Utah. A comprehensive report on high lakes management for the Uinta Mountains should be completed in 1996 pending discussions with interested stakeholders (Tom Pettengill, Utah Department of Natural Resources, Division of Wildlife Resources, personal communication).

High lake stocking has probably impacted the distribution of Bonneville and Colorado River cutthroat trout in drainages below these lakes. However, surveys of remote streams have revealed that a number of pure populations of these subspecies remain in isolated areas (Tom Pettengill, Utah Department of Natural Resources, Division of Wildlife Resources, personal communication). The Northeast Region has stopped stocking Yellowstone cutthroat trout in high mountain lakes, and although the Northern Region continues to do so, it plans to stop stocking them when native subspecies become available.

Recommended stocking densities are based on the general rate of 100 fish/surface acre for rainbow and brook trout, and 200 to 250 fish/surface acre for cutthroat trout and Arctic grayling *Thymallus arcticus*. Cutthroat trout and grayling are stocked at higher densities because they are smaller at stocking (700 to 1,200/lb versus 70 to 90/lb for rainbow trout) and often experience higher mortality rates. Stocking rates may be modified in response to accessibility, fishing pressure, natural recruitment, survival, growth, forage availability, and longevity.

Stocking cycles are based on angling pressure, natural recruitment, survival rates, and growth. Since natural mortality and/or fishing pressure severely reduce fish populations by age 5 or 6, stocking cycles generally do not exceed 4 years in lakes with natural reproduction or lakes managed for trophy fisheries. Extension of stocking cycles beyond 4 years can result in periods of poor fishing as stocked cohorts grow to catchable size in lakes devoid of older age classes. However, in lakes subject to periodic winterkill, a 2-year cycle is used to maintain fishable populations.

In general, brook trout exhibit superior reproductive capability in alpine habitats and will usually predominate. Attempts to establish cutthroat or other species in waters containing brook trout have generally proven unsuccessful, even at low critical densities of brook trout, unless there is no spawning habitat available. However, there are some indications rainbow trout maintained by aerial stocking are able to compete with brook trout due to the large average size of stocked rainbow fingerlings (70 to 90/lb). Stocking of brook trout into systems with existing cutthroat or golden trout populations is not recommended. Grayling have been shown to effectively coexist with other salmon ids (even brook trout) by occupying a slightly different niche.

Brook trout growth and condition factors are maximized in lakes characterized by organic substrates and productive benthic communities due to the bottom feeding preference of this species. Brook trout are generally stocked in lakes with a history of winterkill due to the ability of this species to adapt to low dissolved oxygen levels. Grayling are similar to brook trout in their ability to tolerate low dissolved oxygen levels. Cutthroat trout are opportunistic feeders and tend to feed throughout the water column. This species is better suited to lakes with rocky or sandy substrates, or those with fluctuating character.

High mountain lake surveys are conducted in three phases. Phase 1 surveys are designed to collect baseline data for initial development of management plans. Physical (surface area, maximum depth, surface temperature, bottom substrate type, photographs), chemical (pH, bicarbonates, percent bottom organic matter), and limnological (plankton hauls, gill net/hook-and-line fish collection) data are collected. Phase 2 surveys are more intensive and are designed to evaluate fishery status, improve inventory data, and update general user information. Data collected include:

Physical Data
- Surface area, bathymetry, map construction, shoreline development, inlet/outlet flow, percent littoral area, bottom type composition.

Use Data
- Basic creel surveys to obtain rough catch information, angler pressure categorization based upon evidence of fishing activity, access description.

Fishery Data

- Variable mesh M in to 2 in mesh, 6 ft deep, 150 ft floatline, 180 ft leadline) gill nets set perpendicular to shoreline in 5 ft to 15 ft of water, more than one net when lakes are larger than 20 acres.
- Condition factors, visceral fat coefficients, age and growth determination (otoliths preferred), spawning habitat evaluation.

Phase 3 surveys are used to document and evaluate changes in fish parameters. All Phase 2 fishery data are recollected, except for spawning habitat information. Regular surveys are not scheduled after Phase 3.

Utah has an experimental stocking and evaluation program with the goal of providing viable game fish populations in as many of the 1,000 lakes and ponds in the High Uintas as possible within the constraints of the Wilderness Act. Lakes selected for this program contain marginal or questionable habitat conditions and have not been previously managed to provide a fishery. Stocking occurs at normal rates. Follow-up gill net surveys are conducted 2 years after initial stocking to evaluate survival and growth. This allows passage of two winter periods and helps reduce the potential bias of an abnormal winter. It also allows fish ample time to attain an adequate sampling size.

Washington

The alpine lake resource in Washington involves 3,000+ lakes. Over 90% of these lakes were barren of fish prior to stocking, and more than 75% of those require periodic stocking to maintain fishable populations of rainbow and cutthroat trout (Johnston 1977). Alpine lakes are generally managed to provide quality fisheries governed by special regulations.

A maximum stocking rate of 100 fish/acre (all species) has been shown to minimize stunting (defined as failure to attain 6.5 in total length [TL] by age 1). Fish are stocked at 300 to 500 fish/Ib since smaller fish (1,000 fish/Ib) do not reach harvestable size as quickly. Fish are usually stocked by helicopter from August through September, but stocking operations sometimes begin as early as July, depending on ice conditions. A 5-year cycle is used. Since fishing pressure tends to be high in Washington's mountain lakes, most fish do not survive to age 4. A 5-year cycle allows invertebrate populations to rebuild for about 2 years, which promotes fish growth rates resembling those seen after initial stocking events.

Principal component analysis has been used to determine which of 32 environmental variables are important in predicting the TL of rainbow trout at age 3 in north Cascade lakes (Jim Johnston, Washington Department of Fish and Wildlife, personal communication). Eight variables have been found to be significant: ,

- Geology: soil depth, rock formation, etc.
- *Diaptomus kenai* abundance: based on visual observations, qualitative estimates range from low to high. The gill raker spacing in juvenile rainbow trout enables them to effectively exploit this pelagic copepod.
- Caddis abundance: based on visual observations of larval cases, qualitative estimates range from low to high.
- Sedges: volume standardized by lake surface area.

• Drainage vegetation: percent covered estimated from aerial photographs.

• Fish population density: hydroacoustic surveys conducted after emergence and standardized by time of year. Rated as low (< 25 fish/acre), medium (25 to 75 fish/acre), and high (> 75 fish/acre). Low densities are generally associated with non-reproducing populations.

• Conductivity

The mean length of rainbow trout at age 3 in north Cascade lakes is about 11 inches TL. If the analysis of survey data for a particular lake is less than the mean, stocking is not initiated or continued.

Rainbow (Mount Whitney) and cutthroat trout (westslope) are generally stocked, but brown trout are sometimes stocked on top of stunted brook trout populations as a predator. Rainbow trout have also been successfully stocked on top of brook trout populations (Utah reports similar findings). This species can apparently exploit pelagic zooplankters more effectively than brook trout (due to proclivity of the latter species to inhabit littoral areas and the wide spacing of its gill rakers), and can aggressively displace inshore brook trout populations (Jim Johnston, Washington Department of Fish and Wildlife, personal communication).

Wyoming

Wild trout management is the highest priority of the high mountain lake program in Wyoming, followed by stocking of native cutthroat trout (Robert Wiley, Wyoming Game and Fish Department, personal communication). However; virtually all trout species have been stocked at one time or another in Wyoming's high mountain lakes. Many high mountain lakes support brook trout as a result of stocking between 1930 and 1950.

Wyoming's policy dictates barren mountain lakes will remain that way. Where stocking continues, most is done by aircraft. Fry or fingerling fish are most commonly stocked on an alternate year or longer basis. Catchable-sized trout are not used in high mountain lakes. Golden and cutthroat trout are used in the highest elevation lakes, with the latter being stocked most often.

Lakes receiving fish plants are resurveyed every 4 years to monitor fish stocks and evaluate additional stocking needs. Four lakes in the Bridger Wilderness are being monitored as part of the U.S. Forest Service Acid Precipitation Monitoring Program.

Growth is typically slow and food organisms are scarce in high mountain waters. However, trout growth is sometimes excellent, most often in waters where natural reproduction is limited, resulting in populations in balance with habitat and food resources.

Eastern United States

Maine

Maine has 40 lakes over 2,000 feet in elevation, 7 of which are higher than 2,500 feet: only 2 sit at elevations greater than 3,000 feet. Sixteen of the 40 lakes are stocked (Forrest Bonney, Maine Department of Inland Fisheries and Wildlife, Fishery Division, personal communication).

Most high elevation lakes are stocked by airplane with fall brook trout fingerlings, but two are stocked with fry that are backpacked in. Although brook trout growth rates are probably lower than those from lower elevation ponds, no studies have been done to confirm this suspicion. High elevation lakes are stocked at the same rate as other brook trout waters.

New Hampshire

Approximately 60 ponds are aerial-stocked with brook trout (Rome strain) in New Hampshire (Scott Decker, New Hampshire Fish and Game Department, personal communication). These ponds range in elevation from 1,155 to 3,490 feet, and in area from 2 to 117 acres.

Complaints of low catch rates have prompted a return to stocking 150 to 200 fish/surface acre at approximately 150 fish/lb, rather than stocking a few larger fish. Only one or two mountain lakes have self-sustaining populations and are not stocked. Lakes are managed on an individual pond basis. Acidity data and other water chemistry parameters (alkalinity, specific conductance, color, aluminum, magnesium, calcium, sodium, potassium, chloride, sulfate, and calcite saturation index) are collected in the spring, generally on an annual basis by the New Hampshire Department of Environmental Services (Warren and Martin 1988). These data are used for stocking purposes. Two ponds have not been stocked for many years because fish have not done well due to acidic conditions.

New York

High mountain lakes in New York are considerably lower in elevation than those in Idaho, with perhaps one pond or lake higher than 3,000 feet. Higher elevation lakes are most frequently stocked with fall fingerling (0+) wild x domestic hybrid brook trout. In some instances, another species of trout (usually rainbow trout) is stocked along with brook trout fingerlings (Phil Hulbert, New York State Department of Environmental Conservation, Division of Fish and Wildlife, Bureau of Fisheries, personal communication; Keller 1979).

Wild x domestic hybrids are produced by crossing a domestic, furunculosis-resistant strain with wild Temiscamie strain fish from Canada. Compared with pure wild strain fish, hybrid-strain brook trout offer a greater supply of eggs, easier propagation, lower rearing costs, and better initial survival rates after stocking (Keller 1979). Advantages of hybrids over domestic strains include more successful natural reproduction and their tendency to produce quality fisheries under special regulations. Hybrids also provide the highest returns and lowest yield costs per pound. The Temiscamie strain and its hybrids have comparatively high tolerance to acid water conditions. However, the Temiscamie strain and its F1 hybrid exhibit migratory tendencies and are recommended for stocking only in ponds where their egress is blocked.

Preservation of heritage (native) strains is also a concern in New York. To maintain the genetic integrity of wild fish, heritage strain waters or their tributaries are not stocked with brook trout of any other strain or species. Heritage strains are stocked in waters with the best potential for natural reproduction, a reasonable degree of genetic isolation, and satisfactory water quality. Heritage waters are stocked for a maximum of 3 years. If a brook trout population fails to become self-sustaining within 2 years following the final stocking, the use of a particular water body for heritage purposes is discontinued.

Stocking rates are based primarily on Ryder's (1965) morphoedaphic index and are determined as directed, in Engstrom-Heg (1979). Final numbers may be adjusted for competition, contribution of naturally spawned fish, and fishing pressure. The apparent ability of wild and hybrid brook trout to spawn in waters where domestic fish are unable to do so requires flexibility in stocking rates and regulations. Keller (1979) recommends waters stocked with wild or hybrid strain fish be monitored 2 to 3 years after stocking to ascertain spawning success.

Lake acidification is a serious problem, particularly in the Adirondack Mountains. Routine monitoring is required to assess fish stock status and water quality, particularly pH. Successful management of acidified waters necessitates the use of lime- and/or acid-tolerant strains of brook trout. In lakes impacted by acidic conditions and treated by liming, maximum stocking rates and growth rates are limited due to generally lower nutrient levels and shorter growing seasons. Recommended maximum stocking rates for limed lakes are 40 fall brook trout fingerlings/acre every 2 years, or 25 fall fingerlings/acre every year. The latter approach maintains better stock composition and a more uniform year-to-year fishery (Gloss et al. 1989).

IDFG Alpine Lake Fishery Program

For over 50 years, alpine lake management in Idaho has consisted of stocking lakes on a regular basis (usually 2- to 3-year intervals) to assure adequate supplies of fish for anglers. Alpine lakes have been stocked with native salmonids (though not necessarily native to a particular lake), and with exotic species such as brook trout, golden trout, brown trout, Atlantic salmon *S. salar*, Arctic char *S. alpinus*, and Arctic grayling (Van Vooren et al. 1991; Pitman et al. 1996). Species stocked, in order of importance, are cutthroat trout, rainbow trout, cutthroat-rainbow trout hybrids, golden trout, and Arctic grayling (Moore et al. 1986). Although there are exceptions (Bill Horton, Idaho Department of Fish and Game, personal communication), brook trout generally are no longer stocked in alpine lakes due to their tendency to overpopulate and become stunted (Moore et al. 1986) and to competitively interact with native species.

Some of the most intensive alpine lake investigations and management applications have been implemented in the IDFG Clearwater Region, so the approach from that region will serve as the model for discussion. Bahls (1991) provides a survey methodology which includes collection of the following data:

Physical Data

- Lake surface area, surface elevation, maximum depth.
- Percentage shallow (< 10 ft) littoral zone.
- Percentage bottom composition of the lake shoreward of 10 ft contour.
- Surface and deep (5 ft above lake bottom) water temperature.
- Major inlet and outlet data, including stream width, depth, flow velocity, percentage sand/gravel, barrier type, potential alluvial spawning areas, number of fish observed, and number of inlet seeps.

Water Chemistry

- Shallow (5 ft) and deep l5 ft above lake bottom) water conductivity.
- Shallow and deep water pH.
- Shallow and deep water alkalinity.

Biological Data

- Shallow zooplankton: two 15 ft to 20 ft horizontal hauls from shore spaced 30 ft apart with a 153 micron mesh plankton sampling net.
- Deep zooplankton: two vertical bottom to surface hauls in the deepest area of the lake.
- Aquatic invertebrates: visual scan of nearshore area every 30 ft along lake perimeter and samples.
- Freshwater shrimp: species present in nearshore substrate in aquatic invertebrate sample.
- Terrestrial lakeshore vegetation: percent coverage by vegetation types in a 30 ft strip around lake, open ground percentages and type. Note: research in California (Chase 1992) and Washington (Jim Johnston, Washington Department of Fish and Wildlife, personal communication) suggests the surface area of meadow habitat draining into a lake and/or the percent of a drainage covered by vegetation may be important productivity variables.
- Animal observations.

Fish Population Data

- Fish species present: 12 h variable mesh gill net (seven panels: ½ , ¾, 1, 1 ¼, 1 ½, 1 ¾,, and 2 in mesh; 165 ft long; 5.9 ft deep) set perpendicular to shore, and angling. Note: one net is probably insufficient in some cases. See the discussion for Colorado (Nelson 1988) and Utah (Wilson and Pettengill 1986 and 1988).
- Stocking record.
- Catch ratio: ratio of numbers of each strain or species caught by gill net and angling.
- Total length, weight, stomach contents, otoliths.
- Natural reproduction: correlation between length-age frequency and stocking records, observation of juvenile fish, spawning habitat estimate.

Human Use and Impact

- Number of anglers and non-anglers observed.
- Campsite impact: size, degree of impact.
- Access difficulty rating: distance from road, distance on minor trail, distance bushwack.

Lake survey data provide the basis for the following lake management classifications Bahls 1992):

I. Fishless lake - no fish present
   a. Record of past stocking.
   b. No record of past stocking.

II. Wild trout lake - natural reproduction occurs
   a. Low to moderate level of natural reproduction.
   b High level of natural reproduction.

III. Native trout lake - contains trout native to lake
   a. Possible pure strain of native trout.
   b. Hybrid trout due to past stocking.

IV. Stockable lake - non-reproducing stocked trout present
   a. Not suitable for further stocking: unsuitable habitat (unproductive; small, < 3 acres; shallow, < 12 ft), native trout downstream of outlet, excess recreational impact, other fishery and management considerations.
   b. Suitable for further stocking: lake-specific considerations indicate potential impacts of continued stocking on other wilderness and fishery resource values are acceptable.

V. Further study lake - status of reproduction unknown

Under this classification method, only lakes with non-reproducing, stocked fish populations are considered for stocking (class IV). Wilderness and fishery management considerations are used to evaluate every lake and classify it as unsuitable (IVa) or suitable (IVb) for stocking. Class V lakes have usually been heavily stocked. Further stocking of class V lakes is recommended only after a survey has been conducted 5 to 10 years following the last stocking date to determine if the lake requires supplemental measures.

Fish are usually stocked as fingerlings (1 to 2 in) by fixed-wing aircraft in August or September. A minimum 3-year rotation interval is generally used, although Bahls (1990b) recommends a 4-year rotation to: 1) reduce predation on fingerlings by large existing fish; and 2) reduce slight over-stocking problems.

Stocking rates are estimated for each lake based on characteristics of existing fish populations (condition, maximum length, relative abundance), past stocking records; estimates of lake productivity, and angling pressure. Evidence of stunting or poor condition of older fish and depleted prey bases may require a decrease in historic stocking levels. Bahls (1990b) generally recommends rates of less than 200 fish/acre based on qualitative criteria: general knowledge gained by comparing stocking records to characteristics of fish populations, and consideration of the biological and physical characteristics of a lake. Bahls' (1990b) expressed objective is to produce quality fisheries, defined as low- to moderate-sized populations (angling catch rate = 0.1 to 3 fish/h) containing large fish (> 16 in) in good condition.

Between 1985 and 1995, actual stocking rates have ranged from around 30 to 1,000 fish/acre, but rates of less than 200 fish/acre have been most common (Bahls 1990a and 1990b; Bahis 1992; Cochnauer and Phillips 1994). Historic stocking rates have been reduced in some lakes and stocking has been discontinued in others, either following surveys that have indicated poor survival due to unsuitable habitat or signs of natural reproduction.

Bahls (1990a) describes the relationship of fish condition and maximum length to fish population and habitat variables in a series of stepwise multiple regressions. Independent variables include:

- Species (categorical, 1 or 2): lakes dominated (> 10:1 sampling ratio) by: 1) brook trout; or 2) rainbow and/or cutthroat trout.
- Natural recruitment (categorical, 1, 2, 3 or 4): qualitative estimate where 1 = no evidence of natural recruitment, 2 = possible natural recruitment, 3 = low to moderate natural recruitment, and 4 = high natural recruitment.
- Campsite impact: based on qualitative estimate of percentage duff and perennial vegetation remaining on a site (Bahls 1989) with 1 = low, 2 = moderate, and 4 = high.
- Access distance (log): weighted sum of distance from nearest road with each mile of trail weighted by 1 = main trail, 4 = minor trail, and 8 = bushwack.
- Elevation - lake surface elevation.
- Large Diaptomus: presence (1) or absence (2) of large (> 0.08 in) red pigmented *Diaptomus spp*., as determined from zooplankton samples.
- Bottom substrates (arcsine square root): weighted average of percentage bottom substrates in the shallow littoral zone from 100% silt (1) to 100% bedrock (5).
- Shallow littoral (arcsine square root): percentage of lake surface area between shoreline and 10 ft contour.
- Basin area: watershed area.
- Stocking rate: estimated stocking density during a 7-year period prior to the year of survey assuming 90% survival. Stocking rate was calculated as the sum of annual survival per surface acre for each stocking that occurred during the 7-year period.

Bahls' analyses indicated: 1) condition and maximum length increased with decreasing natural recruitment; 2) increased angling pressure (campsite impacts and decreased access distances) was related to increased condition (higher angling pressure resulted in smaller fish populations with more food available for remaining individuals); and 3) presence of large *Diaptomus* was related to increased maximum length. Stocking rate, as measured, was not a significant predictor of fish population characteristics. However, stocking density was difficult to estimate and may not have been adequately represented in the model.

DISCUSSION

Comparisons between the IDFG alpine lake program in the IDFG Clearwater Region and those in other states with respect to stocking rates, fish size at stocking, time, and rotation interval indicate management practices are quite similar. Fish are usually stocked as fry or fingerlings (mostly fingerlings in the IDFG Clearwater Region), and base stocking rates for Arctic grayling, cutthroat trout, and rainbow trout generally range from 100 to 250 fish/acre (generally less than 200 fish/acre in the IDFG Clearwater Region). Fish are usually stocked sometime between July and September, depending on ice conditions and fish availability (August to September in the IDFG Clearwater Region). Rotation intervals between 2 to 4 years are common (3 years in the IDFG Clearwater Region).

Although similar to nationwide programs in many respects, can the quality of the alpine lake experience and the condition of mountain lake ecosystems in Idaho be improved by adopting unique management strategies from other parts of the country? Some states are reducing or eliminating exotic introductions, maintaining fishless lakes, terminating stocking of lakes where natural reproduction occurs, and refining stocking rates based on productivity and fish population characteristics. The IDFG 1996-2000 Fisheries Management Plan (Pitman et al.

1996) is in agreement with these principles and provides guidelines for development of a Comprehensive Alpine Lakes Management Plan, which include:

1. Maintenance of fishless lakes in each major drainage.
2. Maintenance of self-sustaining trout populations.
3. Maintenance of species of special concern and threatened and endangered species.

Part of the alpine lakes comprehensive plan calls for development of an assessment manual based on the physical and biological parameters of a lake, the intent of which is to refine stocking practices that avoid indiscriminate stocking due to a lack of survey data. The question is what type of data should we collect, how often should we collect it, and how do we interpret it? Work done in other states and in the IDFG Clearwater Region provide some direction.

Data that permit categorization of lakes into the fishery management classifications discussed in Bahls (1992) should be collected on a regional basis. To this end, an abbreviated and slightly modified version of Bahls (1990a and 1991) survey procedure should suffice. At a minimum, the following data should be collected:

Physical Data

- Geology: drainage characterized by soil formation or bedrock. Note: although Bahls did not consider this variable, research in Washington (Jim Johnston, Washington Department of Fish and Wildlife, personal communication) suggests this is an important productivity indicator.
- Lake surface area, surface elevation, maximum depth.
- Percentage shallow (< 10 ft) littoral zone.
- Presence or absence of potential alluvial spawning area.

Water Chemistry

- Shallow (5 ft) and deep (5 ft above lake bottom) water conductivity.
- Shallow and deep water alkalinity.

Biological Data

- Zooplankton: presence or absence of large (> 0.08 in) red pigmented *Diaptomus spp*. as indicated by one vertical bottom to surface haul with a 153 micron mesh plankton net in the deepest area of the lake. Note: research in Washington (Jim Johnston, Washington Department of Fish and Wildlife, personal communication) has indicated *Diaptomus* abundance is an important productivity indicator. Abundance is based on visual observation and is ranked from low to high. Since this is a subjective evaluation, presence or absence of large specimens may be easier information to collect.
- Aquatic invertebrates: Presence or absence of invertebrates based on visual scan of nearshore areas. Gross identification is sufficient, e.g., caddis, stone fly, etc. Note: research in Washington (Jim Johnston, Washington Department of Fish and Wildlife, personal communication) has indicated caddis abundance based on visual observation of larval cases is an important productivity indicator. Abundance is ranked low to high. Since this is a subjective evaluation and other taxa may be important, presence or absence of predominant groups may be easier information to collect.
- Aquatic vegetation: percentage of lake surface covered by predominant vegetation type. Gross identification may be sufficient, e.g., sedge, aquatic moss, etc. Note: research in Washington (Jim Johnston, Washington Department of Fish and Wildlife, personal

communication) and California (Chase 1992) has indicated *Carex* and *Potomogeton* are important productivity indicators.

- Terrestrial vegetation: percentage of drainage covered, from aerial photographs.

Fish Population Data

- Fish species present: 12 h variable mesh sinking gill net (seven panels: ½, ¾, 1, 1 ¼, 1 ½, 1 ¾, and 2 in mesh; 165 ft long; 5.9 ft deep) set perpendicular to shore, and angling. Note: one net is probably insufficient in some cases. See the discussion for Colorado (Nelson 1988) and Utah (Wilson and Pettengill 1986 and 1988).
- Stocking record. Note: research in Washington (Jim Johnston, Washington Department of Fish and Wildlife, personal communication) has indicated hydroacoustic fish density estimates, measured after emergence and standardized by time of year, are an important productivity indicator. Density is ranked low to high. Since this is a labor intensive operation involving expensive equipment, it is probably beyond the scope of regional resources. Using stocking records may not be a suitable surrogate for fish densities, but stocking records should be recorded.
- Total length, weight, otoliths.
- Natural reproduction: correlation between length-age frequency and stocking records, observation of juvenile fish.

Human Use and Impact

- Number of anglers and non-anglers observed.
- Campsite impact: size, degree of impact.
- Access difficulty rating: distance from road, distance on minor trail, distance bushwack.

Once lakes are classified as suitable or unsuitable for stocking, stocked lakes should be stratified by stocking regime, e.g., low (< 200 fingerlings/acre), moderate (200 to 300), and high (> 300), and species stocked.

The next step is to evaluate the influence of these stocking densities on the length of fish at, say, age 3. Data from stocked lakes in geologically similar areas of the state would be pooled by stocking regime and species and regressed on the length of fish at age 3. A series of stepwise multiple regressions, principal component analysis, or some other vehicle could be used to develop a model for each stocking regime and species. These models would then be used to analyze the *unpooled* data. The model that predicts the highest average length at age 3 could then be used to establish the baseline stocking rate. The model predictors will determine what type of data are collected in subsequent surveys. Thus, the more parsimonious the resulting model is, the less rigorous subsequent surveys will be. Until enough data are collected for the above regressions, a stocking rate of 200 or less fingerlings/acre is recommended.

A management criterion against which the baseline rate could be evaluated would need to be developed, say production of 11 in fish at age 3. If the model predicted fish stocked in a particular lake would not meet the management criterion, a manager may decide to adjust the baseline rate downward, postpone, or discontinue stocking (unless anglers are happy).

Stocking intervals nationwide generally range from 2 to 4 years. Easily accessible, heavily-fished lakes may be stocked as often as every year, while remote lakes with light use may be stocked once every 4 years. Shorter intervals can help maintain better stock composition and a more uniform year-to-year fishery when fishing pressure is high. However, longer rotation cycles can promote recovery of invertebrate populations. In short, rotation cycles should be based on access, fishing pressure, lake productivity, and angler preference.

Ideally, a lake should be surveyed one year previous to a scheduled stocking event. This may not be possible in some cases. However, as pointed out by Nelson (1988), trout populations in high mountain lakes are relatively stable when they are maintained by stocking or natural reproduction. Nelson recommends subsequent surveys be based on the knowledge or expectation that changes have occurred or will occur (through changes in fishing pressure, regulations, etc.), and a minimum 5-year survey cycle in lakes where changes are expected.

Another important consideration is stocking strains and species that survive and grow best in the high lake environment without impacting native fish. In terms of reproductive success, traditional strains of domestic (C2) westslope cutthroat may be more successful than rainbow or Yellowstone cutthroat trout (Bahls and Stickney 1988). A new hatchery strain of pure westslope cutthroat may be even more reproductively successful than the strains of cutthroat and rainbow previously introduced, but introductions of this fish may result in dense, stunted populations; Bahls (1990b) cautions that research needs to be conducted to determine its reproductive abilities in high lake habitats and potential impacts to indigenous westslope cutthroat populations. Bahls and Stickney (1988) noted many outlet streams contained reproducing populations of exotic cutthroat and/or rainbow trout that theoretically had access to major river systems. The point here is we should strive to reduce exotic-to-drainage introductions and continue to research and develop native strains.

RECOMMENDATIONS

The following recommendations are restricted to fisheries management and do not attempt an interpretation of the Wilderness Act or other pertinent land management guidelines:

1. Continue to collect data (as outlined in the Discussion section) to categorize lakes by the fishery management classifications given in Bahls (1992).

2. Refine stocking practices by developing models based on productivity and fish population characteristics, and stock at 200 or less fingerlings/acre until these models are developed.

3. Stock every 2 to 4 years depending on access, fishing pressure, lake productivity, and angler preference.

4. Resurvey lakes at least every 5 years when changes in a fishery are expected.

5. Continue to reduce exotic-to-drainage introductions, continue research and development of native strains, conduct further research on the effects of lake stocking on indigenous trout in downstream systems, and determine angler preferences.

6. Develop a high mountain lake database and assessment manual by 2000.

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Project Cost

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